EFFECT OF MOISTURE AND CLAY ON MOULDING PROPERTIES OF COMPOSITE SAND OF RIVER GONGOLA ALONG ASHAKA FOR FOUNDRY USE

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ABSTRACT —This study assessed the effect of moisture and clay and the suitability of river Gongola sand for foundry use. The objectives of the study are to determine the chemical properties of the Gongola river sand and the impact of clay and moisture contents on the properties of the sand. In addition, the study determines the suitability of the sand for foundry use through casting some engineering components. The American Foundry Men's Standards (AFS) was adopted for all samples preparation and tests. The tests were conducted with varied amount of binder and water. The result shows that the sand has high silica content of 80.4% and less impurities of 7.49%. The sand also has good Grain finess number ranging from 45 to 61.89 which is considered adequate for both green and dry casting which is consistent with AFS standard. Gongola sand also exhibits sufficient strength for both ferrous and non ferrous casting at 9% and 12 % clay, but gives weak results at 3% and 6% clay. The findings of the study indicate that river Gongola sand have high silica content with less impurities, good grain finess number as well as good moulding propertie such as; low moisture content, good mouldability and good. Therefore, these findings would be useful to foundries in Nigeria as the sand has good moulding properties and can thus, substitute the imported sand from abroad.

Index Terms— Flowability, Grain finess number, Moisture Content, Mouldability, permeability, refractoriness, thermal shock resistance.

1. INTRODUCTION

Foundry is the field of engineering that deals with production of castings. It has been found to be an important source of industrial emancipation and economic self-reliance in Nigeria (Ihom *et al*, 2014). Casting plays important roles in production of modern equipment for transportation, communication, power, agriculture, agro-allied, construction, space, chemical and petrochemical, and other industries. Using foundry techniques it is easy to produce devices and equipment that are very difficult to produce by other engineering processes.In castings, products with either regular or irregular shapes in various sizes and quantities are made to close tolerance with little metal waste (Shuaib-babata and Olumodeji,2014).A local source of good foundry sand is a generic problem faced by foundry industries, good sand has to be transported from one area to another, though silica sand is of low value, but the cost of transport over a long distance contributes significantly to high cost of production in foundry. This forced foundry operators to locate their foundries closer to the source of raw materials otherwise a synthetic sand has to be used (Uhourtu, 2006). As part of effort to find suitable sources of foundry sand very few researches have been carried out in north eastern part of the country. Therefore, foundry industries, a lot of researches had been carried out in different parts of the country among which are; Lagos, Niger, Osun, Ilorin, Kaduna, Elasha, Benue, Kano, but only in this region have inadequate information on the suitability of moulding sand around them, this can only be achieved by **conducting a research with an in-depth laboratory tests. We found only one study conducted on river Gongola sand** along Dindima in Bauchi State which serves as a source of foundry sand for the local foundries around Bajoga and Gombe state at large. Therefore this research will provide useful information for the foundries about the sand they normally use. This research will also identify a potential moulding sand in Gombe.

2. MATERIALS AND METHODS

The materials used for this study were; sand sample, sodium chloride, lime stone, potasium chloride, aluminum scraps, cast iron scraps, bentonite, distilled water, caustic soda solution, calcium carbide, hydrogen tetraoxosulphate (vi) acid, resin (molasses), plywood, top bond glue, nails, body filler and water.

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2.1 Equipment and Tools

The equipment and tools used in this study included George Fischer model, sieve rack, calibrated container, sieve shaker, digital scale, speedy moisture teller, standard weight scale, drying oven, sand clay washer,desiccator, laboratory sand rammer, standard permeability meter, specimen tube, universal sand strength testing machine and holder for compression test and shear. Others included refractoriness test mould, hydraulic press, mouldability testing machine, energy dispersive-ray fluorescence spectrometry (ED-XRFS), 300 kg rotary furnace, 5 kg bale out crucible furnace, car and motorcycle engine connecting rods patterns, core boxes, G-clamp and grinding plate pattern. These equipment and tools are available at National Metallurgical Development center (NMDC) Jos.

2.2 Methods

American Foundrymen Society (AFS) standard methods (AFS, 1996) were adopted for this research.

2.2.1 Samples and Sampling Techniques

The sand samples were collected from four different places at an interval of 1 km with two points from each place. These points are; A_1, A_2, B_1, B_2, C_1, C_2 and D_1, D_2. From each point two samples were collected at depth interval of 30 cm each. The total numbers of samples were 2*2*4 = 16 from which five samples were made S_1, S_2, S_3, S_4 and composite, C_s. The following are coordinates of each sampling point as given in Table 1.

Table 1

Coordinates of sampling points

Sampling Points	Longitudes(ºE)	Latitudes(ºN)
A_1	11.52100515	10.88532811
A_2	11.52208379	10.88524715
B_1	11.52777965	10.89156254
B_2	11.52834075	10.89122022
C_1	11.52500930	10.89963756
C_2	11.52775596	10.89950677
D_1	11.52463358	10.90877342
D_2	11.52585763	10.90890617

2.3 Experimental Design

Experimental design for this research was carried out with varied amount of water and clay contents (modified). 4^2 factorial design was used; there are two factors (%clay and %water), four levels and 1 number of replication. Number of runs for this research was determined using the formula $N=L^k{*}n$ where k is the number of factors, L is the number of levels and n is the number of replication. This gives the number of samples as $4^2{*}1= 16$.

2.4 Specimen preparation

For this research four different levels were used repeatedly with 4%, 6%, 8% and 10% of water and 3%, 6%, 9% and 12% of clay while the percentage of composite sand ranged from 78% to 93% as balance. These percentages of water, clay and sand by weight were put into a laboratory mixer and then mixed for about five minutes. Thereafter, 160 g (standard) of the mixture was poured into specimen tube and then rammed with three blows of standard rammer weighing 6.6 kg. After ramming, the specimens were ejected except for permeability in which the tests were carried out while the specimen was inside the tube. This procedure was repeated for all the preparations.

3. RESULTS AND DISCUSSION

3.1 Chemical Composition

Figure 1 shows the chemical composition of River Gongola sand. From the elemental analysis the sand has high silica content of 80.4% and 4.5% of alumina (Al_2O_3).

Other major constituents are 5.5% K_2O, 2.11% Fe_2O_3 and other impurities amounting to 7.49%.

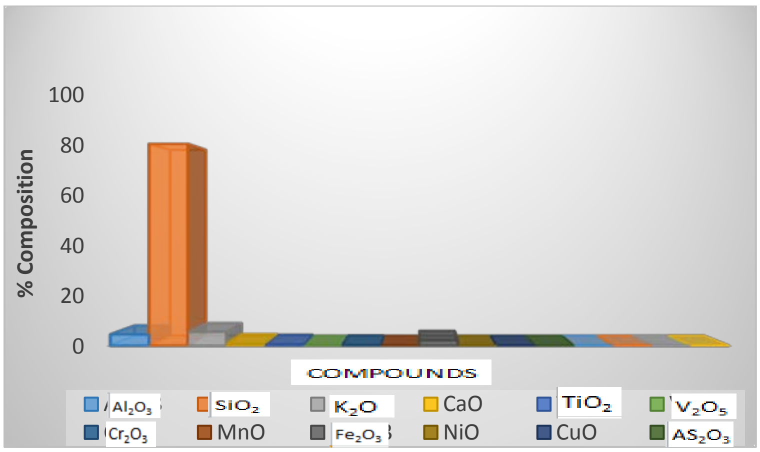
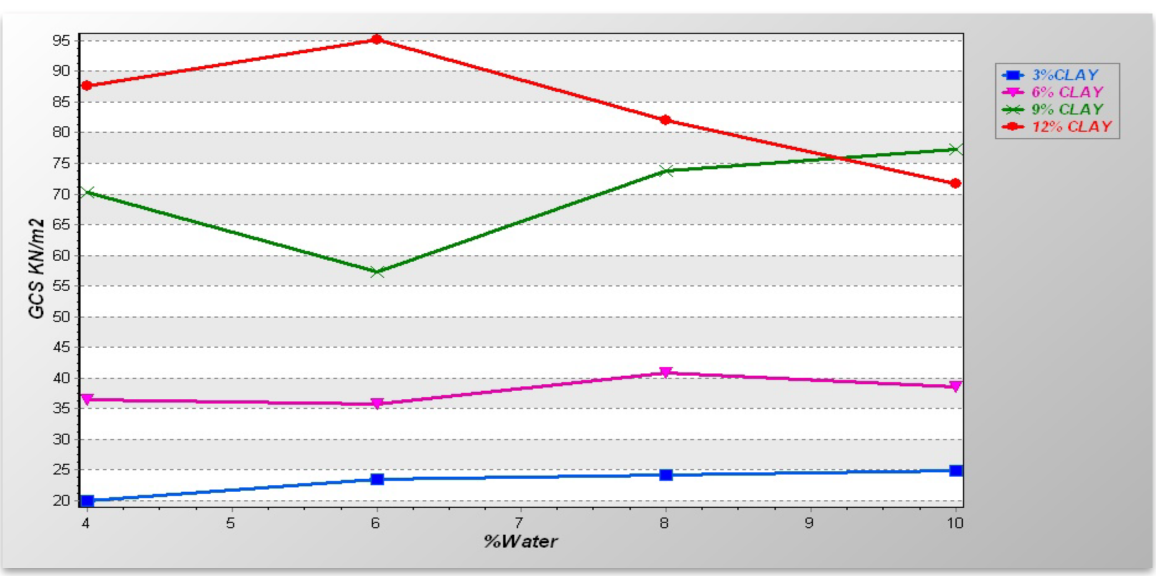


Figure 1: Elemental Analysis of River Gongola sand

3.2 Effect of moisture and clay addition on strength and mouldability properties of composite sand

3.2.1 Strength properties

Figure 2 and 3 reveals that for composite sample C_s at 3% clay and 4%, 6%, 8% and 10% water addition the green compression was between 20 kN/m² and 24 kN/m² which is considered inadequate for green sand casting, as the minimum requirement is 30 kN/m² to 160 kN/m² (Sharma, 2005) while at 6% clay and 4%, 6%, 8% and 10% water addition, the results were between 35 and 40 kN/m² which is equally considered weak for metals with high melting temperature, but sufficient for dry sand casting. On the other hand at 9% , 12% clay and 4%, 6%, 8% and 10% water addition, the results were between 57 kN/m² and 95 kN/m² for green strength and 565 kN/m² and 896 kN/m² for dry compression strength respectively, which is



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considered sufficient for both green and dry sand casting (Sharma, 2005).

Figure 2: Green Compressive Strength for Composite Sample C_s

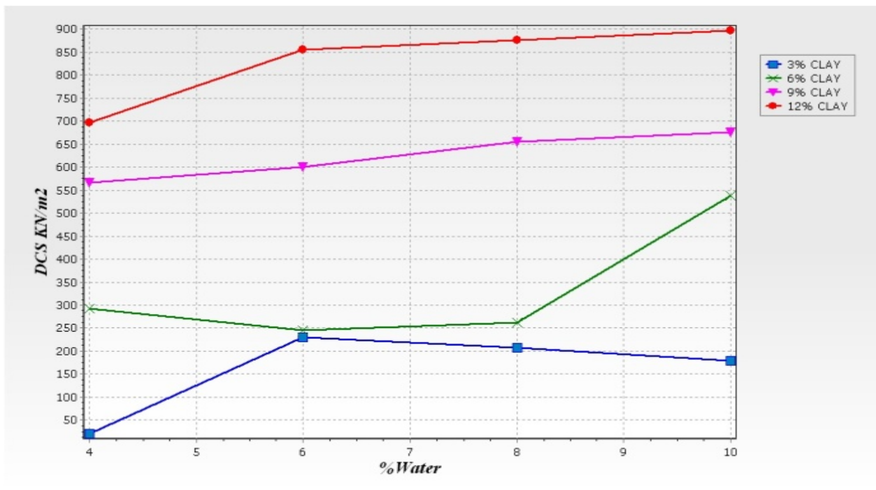

Figure 3: Dry Compressive Strength for Composite Sample

Figure 4 presents the green shear strength which decreases gradually with increase in water, at 4% water, 9% clay and 12% clay the sand has the highest value of 99.97 kN/m². This value decreases gradually to 49 kN/m²and 45 kN/m²at 6% water, then further decreases to 47 kN/m² and 41 kN/m² at 8% water and finally decreases to 25 kN/m²and 47kN/m² for 12% clay at 10% water for 9% clay and 12% clay respectively. The trend for 6% clay was similar. However, the 3% clay differs in which the green shear increases with increase in %water due to the fact that the % clay is small, so addition of water increases the strength, but this strength is below the standard requirement. While for the dry shear on the other hand at 12% clay and 4% water the sand has the lowest value of 310 kN/m² (Figure 5). It gradually increases with increase in % water up to 603.28 kN/m²at 10% water. The other two trends (6% and 9% clay) are similar with the highest value of 439kN/m² and 295 kN/m² respectively. But the one at 3% clay differs in which the dry shear strength decreases with increase in percentage water due to the fact that the clay was low and the drying process reduces the water. High moisture content is not desirable as it decreases the permeability which results in casting defect.

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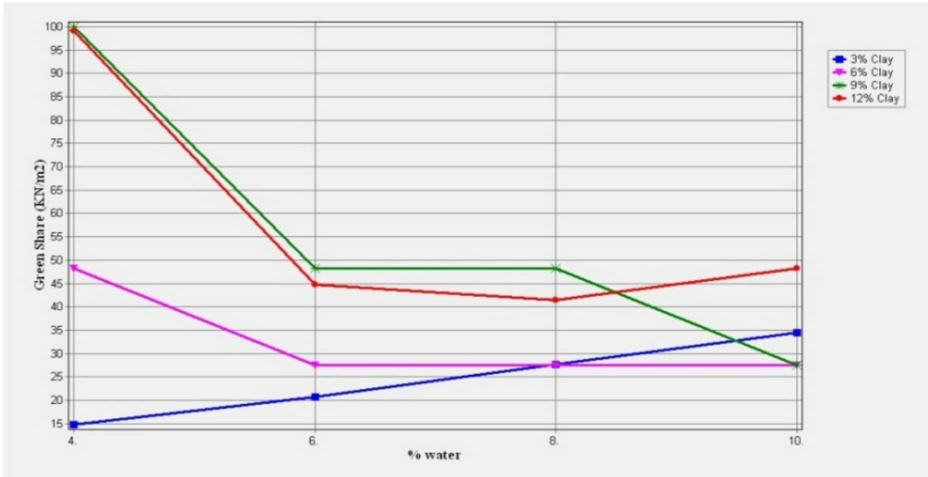

Figure 4: Green Shear Strength for Composite Sample

Figure 5 presents the dry shear strength which increases gradually with increase in water, but too much strength is not desirable as it gives difficulties during knock out.

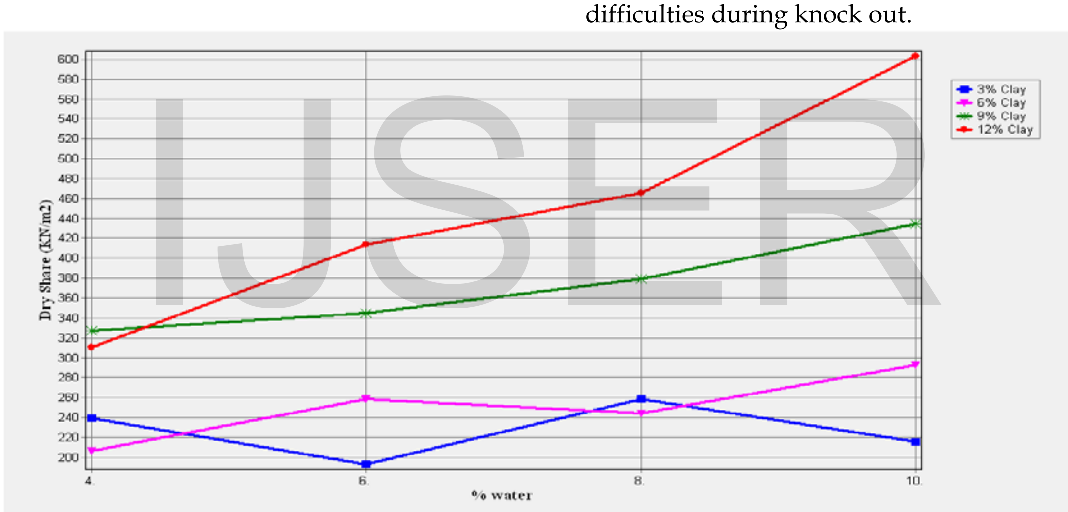

Figure 5: Dry Shear Strength for Composite Sample

3.2.2 Mouldability of composite sample

Figure 6 presents the results for mouldability for composite sample. The results suggest that the mouldability increases with increase in water. The results for 6%, 9% and 12% clay ranges from 5.6 to 10.7 which are consistent with AFS standard of (1 to 11%). On the other hand the result revealed that 3% clay gave poor results with mouldability values ranging from 14.3 to 19.0 which is considered high according to AFS standard.

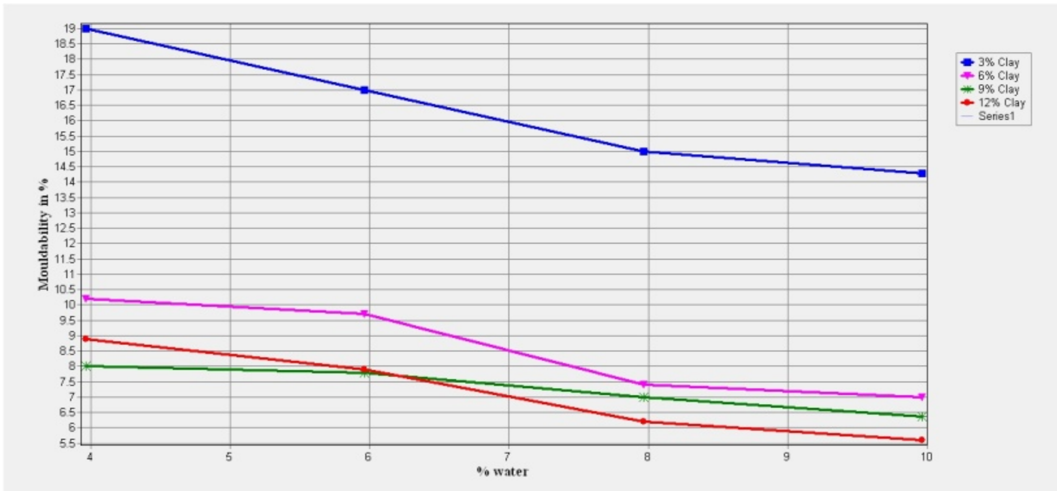

Figure 6: Mouldability for Composite Sample

3.2.3 Casting Finish

Figure 7- 9 presents the unmachined casting made using Gongola sand as moulding material, after the knock out and physical inspection of the cast. Parts were found to be fairly good in terms of defect free, surface finish and dimensional accuracy which requires little machining.

Figure 7: Unmachined mortor cycle connecting road

Figure 8: Unmachined Grinding plate

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Figure 9: Unmachined motor car connecting road

3.2.4 Discussion of Findings

The chemical analysis reveals that the River Gongola sand has high silica content (SiO_2) of 80.4 % which is an indication that it will have good refractoriness and thermal shock resistance (Ayoola *et al*, 2013). The presence of red iron oxide (hematite, Fe_2O_3) which is low would help so that the mould would not stick to the molten metal during casting of ferrous metals (Amare, *et al.* 2014). The presence of potassium oxide can cause objectionable lowering of the fussion point in the sand as cited in some studies (Ayoola *et al*, 2013, Mohd *et al*, 2012 and Amare *et al*, 2014). The alumina oxide (Al_2O_3) present lowers the refractoriness and permeability (Amare, *et al*, 2014) but this alumina oxide can be reduced by washing the sand thereby reducing the natural clay before moulding.

While for the composite sand sample C_s, the clay and water were varied as 3%, 6%, 9% and 12% clay and 4%, 6%, 8% and 12% water in order to determine their effects on the properties of the sample. The results suggest that 3% clay and 4 to 10% water was not suitable as it gives poor results ranging from 20 kN/m^2 to 24.82 kN/m^2 for green compression strength and 14.78 kN/m^2 and 34.47 for green shear strength. However, the results suggest that 6% to 12% clay are suitable for river Gongola sand as it gives a better results which are consistent with AFS. This is consistent with Amare *et al* (2014), Sharma, (2005), Atanda *et al* (2012), Fatai *et al* (2011), among others. The permeability number for all the samples are in conformity with AFS standard of 10 ml/min to 300 ml/min. Therefore the sands are considered suitable for all types of casting with respect to permeability.

Moulds were made using river Gongola sand with 9% clay and 6% water, components cast were grinding plates, motor car connecting rods and motor cycle connecting rods. The materials used were aluminum and grey cast iron, for the aluminum castings they are very good in terms of quality and surface finish. While for the grey cast iron are fairly good. The castings were defect free, less surface roughness and also the dimensional accuracy was appreciable as can be seen in Figures 7- 9, thus, river Gongola sand can be said to be very good moulding sand and is suitable for both ferrous and non ferrous metals.

4. Conclusions

From the chemical analysis, river Gongola sand was found to have high silica content of 80.4% and some impurities amounting to 7.49%. Therefore, river Gongola sand is considered to be high grade silica sand and it is better than many of the river sand in Nigeria found in literature.The clay contents were in the range of 6% and 14.48% which is inconsistent with required standard, therefore care should be taken on how to control other parameters such as %water, so that the moulding sand will be under control.Composite sample in which the %clay and %water were varied at 3%, 6%, 9% and 12% clay and 4%, 6%, 8% and 10% water respectively, the green strength at 3% clay gives a poor results ranging of 20 kN/m^{2}and 24.8 kN/m^2 as such, it is below the recommended strength for all type of casting. While the green strength and dry strength for 6% clay, 9% clay and 12% clay were consistent with AFS standard and

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can be used for all type of casting.The mouldability for composite sample in which the %clay and %water were varied gives a good results with values ranging from 5.6 to 10.7 which is adequate for all type of moulding, the mouldability increases with increase in % water, except for 3% clay. Thus, the river Gongola sand is suitable and efficient for casting as evident from the castings made with grey cast iron and aluminum which had good surface finish and were defect free. This study identified potential good moulding sand, which could be used by foundries around Gombe and Nigeria at large, because it is cheap and readily available, this will consequently reduce the cost of production. The research adopted the AFS standard which makes it more reliable and efficient. The results are very interesting and better than most of the sand worked on in Nigeria. Very few of the silica sand from literature have properties similar to river Gongola which can be used to cast both ferrous and nonferrous metals. This will enable government and stake holders to establish large or medium scale foundries around Gombe to take advantage of this good moulding sand.

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REFERENCES

Amare, D., Biruk, A., & Merkuz, A. (2014). Foundry Properties of Silica sand Deposits at Blue Nile and Jemma River Basin in Northwestern Ethopia. *International journal of Engineering Technology and Advanced Engineering* 4(4), 979-988.

Ayoola, W.A., Adeosun, S.O., & Oyetunji, A. (2013).Investigation into Foundry Properties of Oshogbo and Saki Silica Sand Deposits.*Annals of Faculty Engineering Hunedoara -International Journal of Engineering*, 1(*3),* 213 –218.

Fatai, O.A.I., Sunday, A., & Davies, O. F. (2011). Optimizing the moulding Properties of recycled Ilaro Silica Sand. *Leonardo Journal of Sciences*, *19*(8), 92–103.

Ihom, A.P., Ogbodo, J. N., Allen, A. M., Nwonye, E. I., & Ilochionwu, C. (2014). Analysis and prediction of green permeability values in sand moulds using multiple linear regression model, *African Journal of Engineering Research*, 2(1), 8–13.

Mohd, S.Z.N., Ismail, R. & Isa, M.I.N. (2012). Preliminary Study on the Potential of east Coast of Peninsular Malaysia's silica for foundry. *International Journal of Materials and Mechanical Engineering, 1(1), 53-56.*

Sharma, P.C. (2005). *A textbook of Production Technology (Manufacturing Process)* (sixth ed) S. Chand & Company Ltd. New Delhi, India.

Shuaib-babata, Y.L.P., & Olumodeji, J. (2014).Analysis of Ilorin Sand Moulding Properties for Foundry Applications. *International Journal of Engineering Research & Technology*, *3*(1), 1520 – 1526.

Uhourtu, M. (2006).*Moulding Properties of Dindima River Sand Using Alkaleri Clay as Binder*. Unpublished Post Graduate Diploma project, Department of Mechanical Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria.